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Design and Development of a 100W, 12V DC Solar-Powered Multifunctional Mobile Sprayer for Agricultural Farms in Cansinala, Apalit, Pampanga

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ABSTRACT

A considerable amount of farmers in the Philippines continue to independently use manual or fossil fuel based sprayers, being labor intensive, expensive, and harmful to the environment. A solar powered multifunction mobile agricultural sprayer was developed. This sprayer utilizes solar energy to help users produce some solutions to fossil fuel-based dependencies, reduced emissions and costs result in all lower operating costs. The sprayer is lightweight and uses a 3 wheel design, which allows users to better navigate uneven and diverse terrains. The single point of operations support of the sprayer and ease of setup allows an individual to be more productive and without support when managing the sprayer systems. Performance evaluations have also indicated that the solar powered sprayer would cover more area under less time, compared to a fully manual or fuel sprayer, which could be a viable operational feature for a farm of all sizes, particularly for farmers with an abundance of non-value generated labor. Although there may be a higher initial cost for the operation of this solar powered system, it could reduce what it cost to grow a food product, and represent 20 plus years of cost savings in labor, fuel, repairs and maintenance. Solar powered agricultural sprayers are minimizing some negative environmental impacts compared to fossil fuels, however its operational abilities demonstrating an awareness of renewable energy and its utility potential for agricultural use should distinguish this moveable mobile sprayer as a worldwide movement, improving productivity of farms, and allowing farmers to seriously engage as part of the global movement to reduce any harmful operating practices towards greener and more sustainable farming systems.

Keywords: Agriculture; Emissions; Productivity; Solar-Powered; Sustainability; Renewable Energy; Environmental Impact; Green Technology; Cost Reduction; Fossil Fuel Alternative; Three-Wheeled Sprayer.

1. Introduction

Pests have historically posed significant challenges to human agriculture for more than 10,000 years, often causing substantial crop losses. Early pest control practices included the use of sulfur in ancient Mesopotamia, as well as other plant-based methods involving toxic chemicals such as nicotine sulfate. These have since evolved into modern practices, such as applying pesticides with sprayers. In 2022–2023, one of the most severe pest outbreaks occurred in Kalinga, Rizal, Philippines, resulting in record-high rice crop losses of up to 70%. Reports revealed that many farmers were unable to effectively control the infestation due to a lack of reliable pest control methods and limited access to electricity. Today, the two most common types of agricultural sprayers are the knapsack sprayer and the boom sprayer. While knapsack sprayers are practical for targeted applications, they are labor-intensive, cover only small areas, and are unsuitable for large-scale use. As agriculture faces growing pressure to increase productivity, it must also adopt sustainable practices. Renewable energy technologies—particularly solar energy—offer a cleaner, more efficient, and precise solution for pest control in agriculture. Solar photovoltaic panels, when paired with a rechargeable battery storage system, can power a DC pump used in a multifunctional mobile sprayer. In response to the challenges faced by farmers, especially in off-grid areas, this study proposes the development of a solar-powered multifunctional mobile sprayer for use in remote agricultural areas such as Cansinala, Apalit, Pampanga. The system promotes the use of renewable energy by reducing dependence on fuel-powered sprayers and minimizing environmental impact. Its compact, mobile design makes it easy for farmers to operate, and its multi-functionality capable of spraying fertilizers, pesticides, and watering plants—enhances

agricultural productivity. This solution supports both national and global initiatives to integrate clean energy into sustainable farming and offers a scalable model for rural communities.

1.1. Study Objectives

1) To design and develop a solar-powered multifunctional mobile sprayer using a 100W, 12V DC system suitable for agricultural applications.

2) To evaluate the performance and efficiency of the solar-powered sprayer in comparison to traditional manual and fuel-powered sprayers.

3) To reduce the dependency on fossil fuels and minimize environmental impact through the use of clean, renewable solar energy.

4) To improve farm productivity and reduce labor requirements by providing a mobile and easy-to-operate spraying system.

5) To assess the cost-effectiveness and long-term operational benefits of using a solar-powered sprayer in local agricultural farms.

2. Materials and Methods

2.1. Framework Diagram

In Figure 1a, the 100-watt solar powered multifunction mobile sprayer is powered by solar power and is agricultural based with a very ecologically friendly and effective renewable power tool. Good mobility, with the sprayer you could take it out for use in remote applications or for other farms where getting an electrical supply is not possible. The sprayer includes a high efficiency solar panel that provides 100 watts of power along with a battery to store the energy. Because of the battery, it will still operate well even in low sunlight conditions. In fact this multi-functional sprayer will be able to perform different operations, like spraying pesticide, applying fertilizer and even misting. It contains a 25L tank which is made from solid materials and is resistant to storing liquids. It has a pump that is providing perfect pressurization, and it also has a solar charge controller for managing energy flow. It is designed to function with minimal maintenance by the users in such a way that it was devised as to allow the users to build a simple sustainable sprayer to use in any environment.

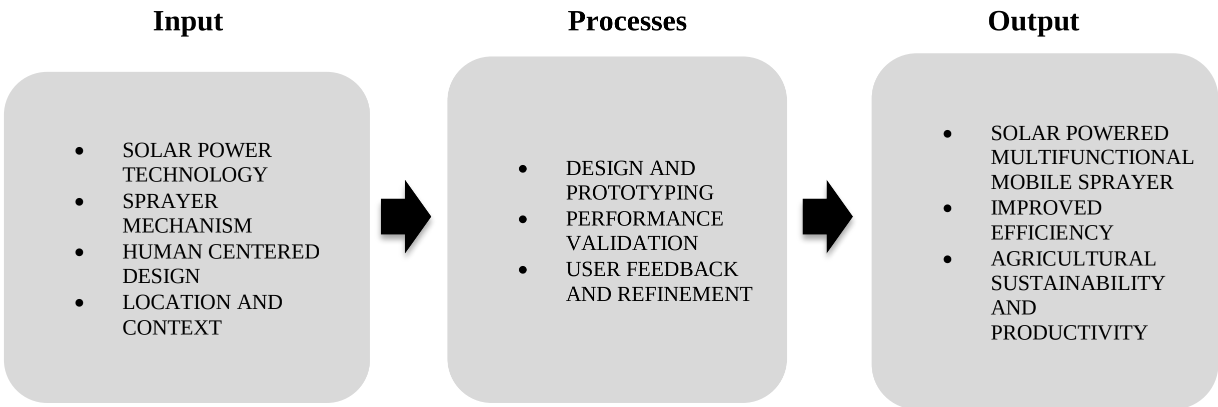

Figure 1a. Framework Diagram

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2.2. Circuit Diagram

The interconnection between the components used in the implementation of the solar water pump is shown in Figure 2a. The DC output from the solar panel is connected in a parallel connection. The SCC is then connected via the DC MCB, as well as the 52 Ah battery used to connect to the SCC via a DC MCB. A DC MCB is needed so that during operation, the operator can easily turn on/off the battery charging from the SCC. The output from the DC battery is then directly connected to the DC Load, which in this case is the DC Water Pump.

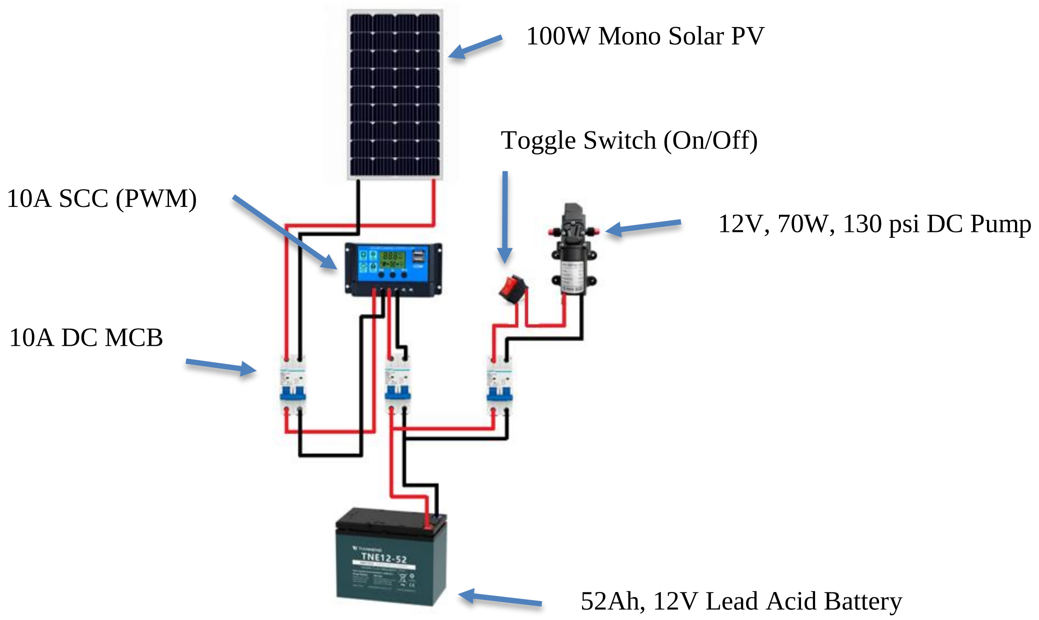

Figure 2a. Circuit Diagram

2.3. 3D Model Setup

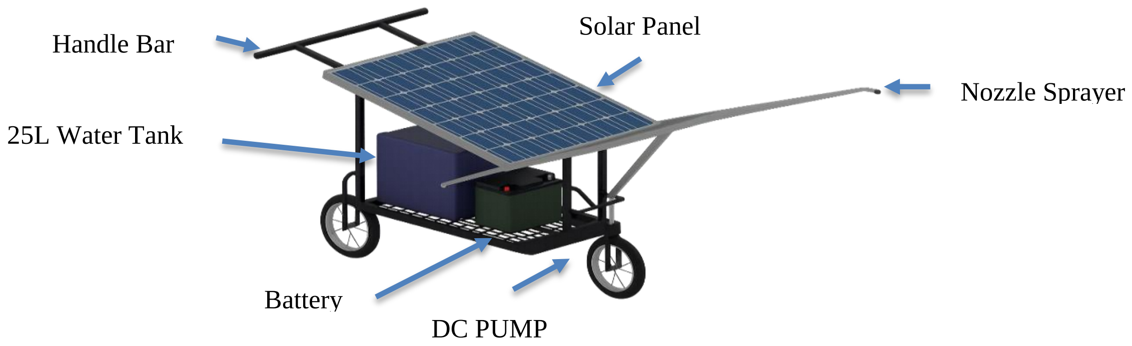

Figure 3a. 3D Model Setup of Solar Powered Multifunctional Mobile Sprayer

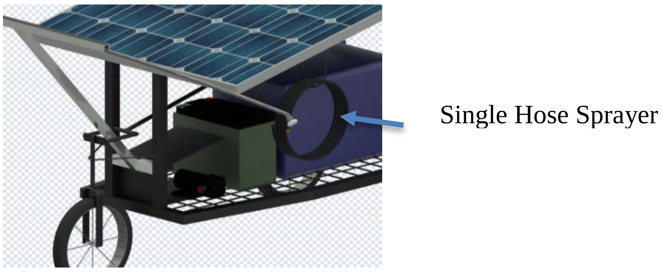

Figure 4a. Single Sprayer Hose

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2.4. Components Used

2.4.1. 100W Solar Panel

A 100W solar panel rated at 17.7V and 6A offers an efficient balance of power and portability. It keeps the 12V battery charged, enabling continuous operation of the DC pump. This clean energy solution is ideal for remote agricultural areas with limited electricity access.

Figure 1b. Solar Panel

2.4.2. 12V, 52 Ah Lead Acid Battery

A 12.8V, 52Ah battery was selected to power the system, providing enough energy to run the pump for several hours on a single charge—ideal for remote fieldwork without charging access. With the pump drawing only 5.83A, the battery supports multiple spraying sessions, ensuring reliable all-day use. Its 12.8V rating also ensures full compatibility with the solar panel and pump for smooth operation.

Figure 2b. Battery

2.4.3. 12V, 70W, 130psi DC Pump (Diaphragm)

A 70W 12V DC pump is ideal for solar-powered sprayers, offering a good balance of performance and efficiency. It delivers 4–6 L/min at up to 130 PSI—suitable for irrigation and crop spraying. Drawing about 5.83A, it pairs well with 12V solar systems, avoiding the need for complex or costly power conversions.

Figure 3b. DC Pump

2.4.4. Nozzle Sprayer

These nozzle sprayers were chosen for their reliability, efficiency, and adaptability in agricultural use. They provide uniform spray coverage for water, fertilizers, and pesticides, and are suitable for various crops and field conditions—boosting productivity and supporting sustainable farming.

Figure 4b. Dual/Single Sprayer

2.4.5. Solar Charge Controller 10A (PWM)

PWM solar charge controllers are cost-effective, reliable, and widely compatible. They regulate power by adjusting pulse width, efficiently managing battery charging to prevent overcharging and extend battery life. Easy to install and suitable for most solar setups, they're ideal for solar-powered systems.

Figure 5b. SCC

2.4.6. 25 Liter Water Tank (Dimension: 40x24 cm^2)

Figure 6b. 25L Water Tank

2.4.7. Compressor Hose ¼

The researchers used a compressor hose for the solar-powered sprayer because it is designed to handle pressurized fluids, making it ideal for delivering a steady and reliable flow of liquid. Its durability, flexibility, and resistance to kinks or leaks ensure efficient operation of the sprayer, especially in outdoor agricultural settings where consistent performance is essential.

Figure 7b. Compressor Hose

2.4.8. 10A DC MCB

DC MCBs are designed to tackle such challenges, ensuring that solar circuits are protected from overcurrent, short circuits, and other potential faults.

Figure 8b. 10A DC MCB

2.5. Design and Calculation Specification

2.5.1. DC Pump Selection

For the design of the Solar-Powered Multifunctional Mobile Sprayer, the researchers assumes a power limit of 100 watts from the solar panel to operate the system.

Assuming an average efficiency of 80%, the usable power was calculated as:

$$Usable\ Power = 100W\ x\ 0.80 = 80W \qquad \ldots(1)$$

Since the system operates on direct current (DC), the researchers selected 12V as the operating voltage:

$$I\ = \frac{P}{V} = \frac{80W}{12V} = 6.67A \qquad \ldots(2)$$

Based on these calculations, the researchers chose a 70-watt, 12-volts, DC pump, as it falls within the available power budget while providing sufficient flow and pressure for the sprayer's operation.

2.5.2. Solar Panel Setup Calculation

A. Calculate total load per day

In the designed solar pump sprayer, the electrical energy requirements are as follows:

DC Water Pump with an average power of 70 Watts, and assuming a daily operating time of 5 hours per day,

So, the total load per day is as follows:

$$E = 70\, watts\ x\ 5hours = 350\, watt - hour \qquad \ldots(3)$$

B. Solar Panel Output Required

$$Solar\ Panel\ Output\ required\ (Watts) = \frac{Electrical\ Energy\ Requirement\ per\ Day (Wh)}{peak\ sun\ hours\ per\ day\ (hours)}$$

$$Solar\ Panel\ Output\ required = \frac{350Wh}{5.19hours} = \ 67.43watts \qquad \ldots(4)$$

The calculated required solar panel output is 67.43 watts after applying a 30% de-rating factor to account for real-world inefficiencies and losses.

$$Adjusted\ Panel\ Size = 67.43\ x\ 1.3 = 87.66\ watts \qquad \ldots(5)$$

Therefore, the recommended Solar PV size is a 100W Solar Panel.

This approach aligns with recommendations from the [1] U.S. Department of Energy's National Renewable Energy Laboratory (NREL) and findings in solar PV technical literature, which suggest applying a de-rating factor of approximately 20–30% to theoretical maximum output to accurately estimate real-world system performance.

C. Battery Capacity Calculation

$$Battery\ Capacity = \frac{Electrical\ Energy\ Requirement\ per\ Day\ (Wh)}{Battery\ Potential\ Difference}$$

For the proposed Multifunction Solar Powered Mobile Sprayer, using a 12 V battery potential difference, the minimum required battery capacity is:

$$Battery\ Capacity = \frac{350Wh}{12Volts} = \ 29.17Ah \qquad \ldots(6)$$

To determine battery capacity, divide total watt-hours (70W × 5h = 350Wh) by voltage (12V), giving 29.2Ah. Adding a 40% reserve for inefficiencies and battery longevity. This approach aligns with [2] (Genus Innovation) industry recommendations for reliable performance and longer battery life. Thus, a 52Ah deep-cycle battery is ideal.

2.6. Vicinity Map

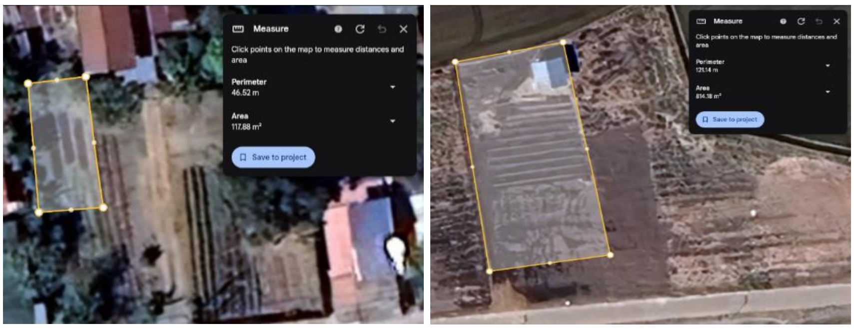

Figure 9b. Field Selected for Testing

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3. Results and Discussion

3.1. Solar PV and Battery Performance Evaluation

Table 1. 5hrs Solar Panel Output Parameters during Load (DC Pump On) and No-Load States (DC Pump Off)

Day	Time	Voc (V)	Isc (A)	Vmp (V)	Imp (A)
Day 1	8-9am	19.3	4.56	17.5	3.61
	10-11am	19.2	4.78	18.5	3.74
	12-1pm	19.1	5.82	18.6	5.08
	2-3pm	19.0	5.8	18.8	5.29
	4-5pm	18.9	5.78	17.2	3.56
Day 2	8-9am	19.4	4.63	17.6	3.67
	10-11am	19.3	4.85	18.6	3.80
	12-1pm	19.2	5.76	18.7	5.10
	2-3pm	19.0	5.79	18.9	5.25
	4-5pm	18.8	5.74	17.5	3.76
Day 3	8-9am	19.2	4.51	17.4	3.55
	10-11am	19.1	4.72	18.4	4.11
	12-1pm	19.0	5.70	18.5	5.0 2
	2-3pm	18.9	5.75	18.7	5.18
	4-5pm	18.8	5.71	17.1	3.12
Day 4	8-9am	19.3	4.58	17.6	3.63
	10-11am	19.2	4.80	18.6	3.78
	12-1pm	19.1	5.81	18.7	5.06
	2-3pm	19.0	5.83	18.9	5.28
	4-5pm	18.9	5.79	16.7	2.9
Day 5	8-9am	19.1	4.53	17.5	3.59
	10-11am	19.0	4.75	18.5	3.77
	12-1pm	18.9	5.79	18.6	5.01
	2-3pm	18.8	5.80	18.8	5.22
	4-5pm	18.7	5.76	17.9	3.14
Total Average:		**19.05**	**5.33**	**18.3**	**4.29**

Table 1 clearly shows the total average Vmp and Imp under load, which are crucial for determining the actual power output of the solar panel. This information is essential for assessing the power required to ensure the overall system operates efficiently. Power Output was calculated using the power formula:

$$P = 18.3\ x\ 4.29 = 78.507\ watts \sim 80\ watts \qquad \dots(7)$$

Based on the calculations, the actual output power was 78.507 W, or approximately 80 W. This indicates that the solar panel operates at about 80% efficiency, given its rated capacity of 100W.

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3.2. Battery Charging Performance

Table 2. Hourly Battery Voltage Measurements during Discharging

Day	Time	Measured Voltage (Discharging)
Day 1	8-9am	12.7
	10-11am	12.3
	12-1pm	12
	2-3pm	11.4
	4-5pm	10.6
Day 2	8-9am	12.6
	10-11am	12.2
	12-1pm	11.9
	2-3pm	12.1
	4-5pm	11.2
Day 3	8-9am	12.8
	10-11am	12.3
	12-1pm	12
	2-3pm	11.6
	4-5pm	10.8
Day 4	8-9am	12.7
	10-11am	12.3
	12-1pm	11.7
	2-3pm	11.5
	4-5pm	10.9
Day 5	8-9am	12.8
	10-11am	12.4
	12-1pm	11.9
	2-3pm	11.3
	4-5pm	10.6

Table 2 presents the battery's discharging voltage levels recorded over five consecutive days, with five hourly readings each day from 8 AM to 5 PM. The measured voltages demonstrate the behavior of a 12V battery under load conditions. Across all days, the battery began discharging in the early morning with voltages typically above 12.6 V, indicating a fully charged state. As the load was applied continuously over several hours, a consistent decline in voltage was observed. By the final time interval each day (4–5 PM), the battery voltage dropped to as low as 10.6 V, approaching the lower operational threshold for many 12V systems.

Table 3. Hourly Battery Voltage Measurements during Charging

Day	Time	Measured Voltage (Charging)
Day 1	8-9am	10.6
	9-10am	11.3
	10-11pm	11.6
	11-12pm	11.9
	12-1pm	12.1
	1-2pm	12.4
	2-3pm	12.7
Day 2	8-9am	11.2
	9-10am	11.4
	10-11pm	11.8
	11-12pm	12.3
	12-1pm	12.5
	1-2pm	12.6
	2-3pm	12.8
Day 3	8-9am	10.8
	9-10am	10.9
	10-11pm	11.3
	11-12pm	11.7
	12-1pm	12.1
	1-2pm	12.5
	2-3pm	12.7
Day 4	8-9am	10.9
	9-10am	11.2
	10-11pm	11.4
	11-12pm	11.8
	12-1pm	12.1
	1-2pm	12.4
	2-3pm	12.6
Day 5	8-9am	10.6
	9-10am	10.9
	10-11pm	11.3
	11-12pm	11.8
	12-1pm	12.2
	1-2pm	12.6
	2-3pm	10.6

Table 3 gives hourly battery voltage readings for a daily period from 8:00AM to 3:00PM for a total of five days. Overall, the daily patterns time period charging period ended at 3:00 PM, contained about 7.1 hours. Given the patterns in advance of those daily time periods, it seems clear that the subject battery would be safely and reliably restored after the battery charging, with only minor variances likely attributable to battery discharge levels before charging and variations in atmospheric conditions.

3.3. Comparative Analysis between a Traditional Knapsack-Sprayer

Table 4 shows the specification of the knapsack sprayer vs the solar-powered multi-functional mobile sprayer for comparison.

Table 4. Specifications

Solar Powered Multifunctional Mobile Sprayer	Traditional Knapsack Sprayer
DC Pump 12V, 130psi, 5L/min	DC Pump 12V, 58psi, 3L/min
25 Liter Tank/6.5 gallons	20 Liter Tank/5.2 gallons
2 Fix Mounted Dual Nozzle Sprayer 1 Single Nozzle Sprayer	Only 1Nozzle Sprayer
Lead Acid Rechargeable Battery 12.8V, 52 Ah	Rechargeable Battery 12V, 8 Ah
46kg Push/Pulling Operation	20-25kg Back-mounted Operation
Electrical energy source for charging: 100W Solar Panel, 17.7V, 6 A	Electrical energy source for charging: 110- 220V outlet

3.4. Area Coverage Comparison

In Figure 10b shows the area covered by the solar-powered sprayer and the conventional knapsack sprayer. The solar model notably outperformed the knapsack sprayer, with a coverage of 598 total square meters or roughly a 25% increase over the knapsack sprayers' 478 surface area coverage. In terms of speeds of use, the solar-powered sprayer covers ground substantially faster than the knapsack sprayer at 107.74 sq.m per minute, whereas the knapsack sprayer barely reached 55.2 sq.m per minute. These results show that the solar-powered sprayer should be more effective and efficient, hence will contribute to improve productivity and reduce time in the field.

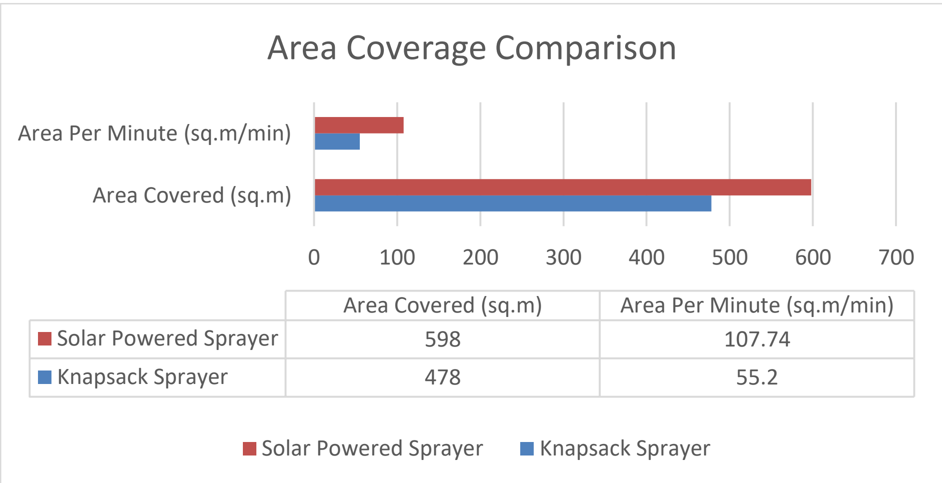

Figure 10b. Area Coverage Comparison (Large Scale Farm)

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3.5. Battery Runtime Comparison

As shown in Figure 11b the data clearly illustrates the superior energy efficiency and extended usability of the solar-powered sprayer, demonstrating that the solar-powered sprayer can be used multiple times over a longer period of days of agricultural activity before its battery requires recharging. In contrast, the knapsack sprayer can typically be used only once per day before it needs to be recharged.

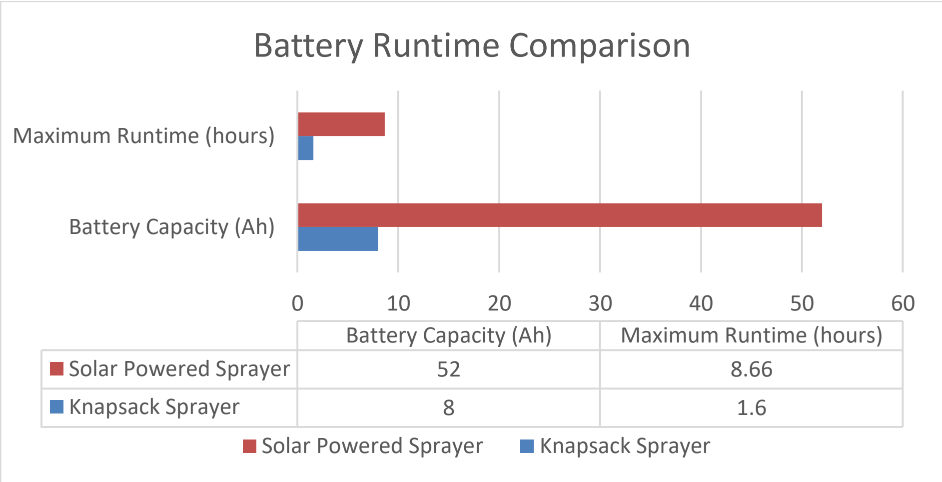

Figure 11b. Battery Comparison

3.6. Total Cost of the Solar Powered Multifunctional Mobile Sprayer

As shown in Table 5 the total construction cost of the sprayer amounted to ₱6,006. While the initial investment for the solar-powered multifunctional sprayer is higher compared to a traditional knapsack sprayer, typically priced between ₱1,900 and ₱3,000 based on the data from two online Philippine markets (Lotus Tools Philippines and Vertex Tool), its operating costs are substantially lower. This reduction is primarily due to the absence of fuel expenses and the decreased labor requirement, as the solar sprayer eliminates the physical burden associated with carrying a knapsack unit.

Table 5. Total Cost

Components	Price (Php)
100w Monocrystalline Solar Panel 17.7v, 6A	1750
70w DC Pump 12v, 130 psi	235
Lead Acid Rechargeable Battery 52Ah, 12.8v	2000
DC MCB 10A	1050
Agricultural Stainless Nozzle Sprayer 60cm	115
10 A Solar Charge Controller	156
#14 AWG Stranded Wire	125
Compressor Hose	195
2 pc Gate Valve	150
11 pc Clamp	110
3 Wheels (junkshop)	120

Scrap Hollow Square Tube 3/4x 3/4	0
Scrap Angle Bar 20mm	0
Scrap Steel Matting	0
Scrap 25 Liter Water Tank	0
Total Cost:	6,006 pesos

4. Conclusion

The solar powered multifunctional mobile sprayer encourages the use of renewable energy in agriculture by using solar power for the purpose of charging a 12.8V, 52Ah battery with a charging time of 7.1 hours, through a 100W solar panel. This system allows extended use for up to 8.66 continuous use or nearly 2 days of moderate daily use without the use of fuel or conventional convenience outlets, that promotes environmental pollution and operational costs. Due to its three wheel setup it allows the system for optimized maneuverability and ease of use over many different surfaces, and it also mitigates operator fatigue and reduces the potential for crop damage as compared to older spraying technologies, making it applicable in different farming environments. Additionally to reduce potential crop damage and operator fatigue the multifunctional mobile sprayer has a multiple nozzle arrangement and a larger 25 liter tank that expands the sprayed area coverage and efficiency of the sprayer, which also outperforms the traditional knapsack sprayer with 25% higher area sprayed coverage rate than conventional knapsack sprayers. This ultimately leads to better productivity by allowing the operator to spray larger areas with less refilling time thus allowing them to complete work faster. Although the solar multifunctional mobile sprayer has a higher initial investment (₱6,006) than conventional sprayers (₱1,900–₱3,000), it does not have fuel costs and operates on reduced labor needs and offers long term cost savings. Overall, the data showed that the solar powered multifunctional mobile sprayer is an effective innovative environmental portable cost saving practical way to improve agricultural productivity and energy sustainability. It addresses key challenges of operator fatigue, fuel dependency, and environmental impact, making it a viable alternative for small to medium-scale farmers, especially in off-grid or remote areas.

5. Future Suggestions

1) To integrate an automatic spraying system using sensors or programmable controllers to further reduce manual input and enhance spraying precision.

2) To incorporate GPS-based navigation or remote control features for autonomous movement and improved field coverage accuracy.

3) To explore the use of recyclable or biodegradable materials in the sprayer's construction for improved environmental sustainability.

4) To implement a basic digital display or indicator system to monitor battery level, solar charging status, and water tank capacity.

5) Finally, to add interchangeable nozzles or spray heads to accommodate different spraying needs such as pesticides, herbicides, or foliar fertilizers.

Declarations

Source of Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Consent for publication

The authors confirm that they consent to the publication of this study.

Authors' contributions

I.J. Mandap and P.I. Manuel were primarily responsible for the conceptualization, design, and mechanical development of the solar-powered sprayer. The entire research group contributed to data analysis and performance testing. I.J. Mandap conducted the final revision and editing of the manuscript. All the authors contributed to the review and approval of the manuscript.

Availability of data and material

Authors are willing to share data and material on request.

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